White Paper

Proposal to DHS/NRSNP Weapon Attribution – Basic Science

Proposal Title: Measurement of Actinide Neutron Cross Sections

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Project Summary:

The maintenance of strong scientific expertise is critical to the U.S. nuclear attribution community. It is particularly important to train students in actinide chemistry and physics. Neutron cross-section data are vital components to strategies for detecting explosives and fissile materials, and these measurements require expertise in chemical separations, actinide target preparation, nuclear spectroscopy, and analytical chemistry. At the University of California, Berkeley and the Lawrence Berkeley National Laboratory we have trained students in actinide chemistry for many years. LBNL is a leader in nuclear data and has published the *Table of Isotopes* for over 60 years. Recently, LBNL led an international collaboration to measure thermal neutron capture radiative cross sections and prepared the Evaluated Gamma-ray Activation File (EGAF) in collaboration with the IAEA. This file of 35,000 prompt and delayed gamma ray cross-sections for all elements from Z=1-92 is essential for the neutron interrogation of nuclear materials. LBNL has also developed new, high flux neutron generators and recently opened a 10^{10} n/s D+D neutron generator experimental facility.

In Berkeley we have seen a sudden influx of U.S. citizen graduate students interested in nuclear chemistry and engineering. We propose to train these new graduate students to prepare actinide targets, measure neutron cross-sections and fission yields on actinide targets, and develop analytical techniques for detecting concealed nuclear materials. The EGAF file will be expanded to include all actinide elements, and extended to include fission and reaction gamma-ray data. Thermal neutron measurements will be performed using guided neutron beams at the Budapest Reactor, 2.5 MeV neutron measurements will be done at the LBNL generator facility, and 14 MeV neutron measurements will use the Rotating Target Neutron Source (RTNS) on the Berkley campus. We will produce new PhD's with expertise in actinide chemistry and physics well prepared to enter the U.S. nuclear attribution community.

Application Description

Prompt Gamma-ray Activation Analysis (PGAA) is a nondestructive method for the simultaneous analysis of all elements, including actinides. Neutrons readily penetrate container walls and interact with concealed materials producing gamma rays unique to each element. PGAA requires a neutron cross-section database for quantitative analysis. LBNL has led an international effort, coordinated by the IAEA, to develop the EGAF database of prompt and short-lived decay gamma-ray cross-sections for thermal neutron capture on all elements from Z=1-92. We propose to extend EGAF to include heavier elements and develop signatures to detect actinides in strategically important materials. In Fig. 1, the PGAA spectrum of 36% enriched uranium, measured with the thermal neutron beam from the Budapest Reactor shows several signatures for detecting uranium.

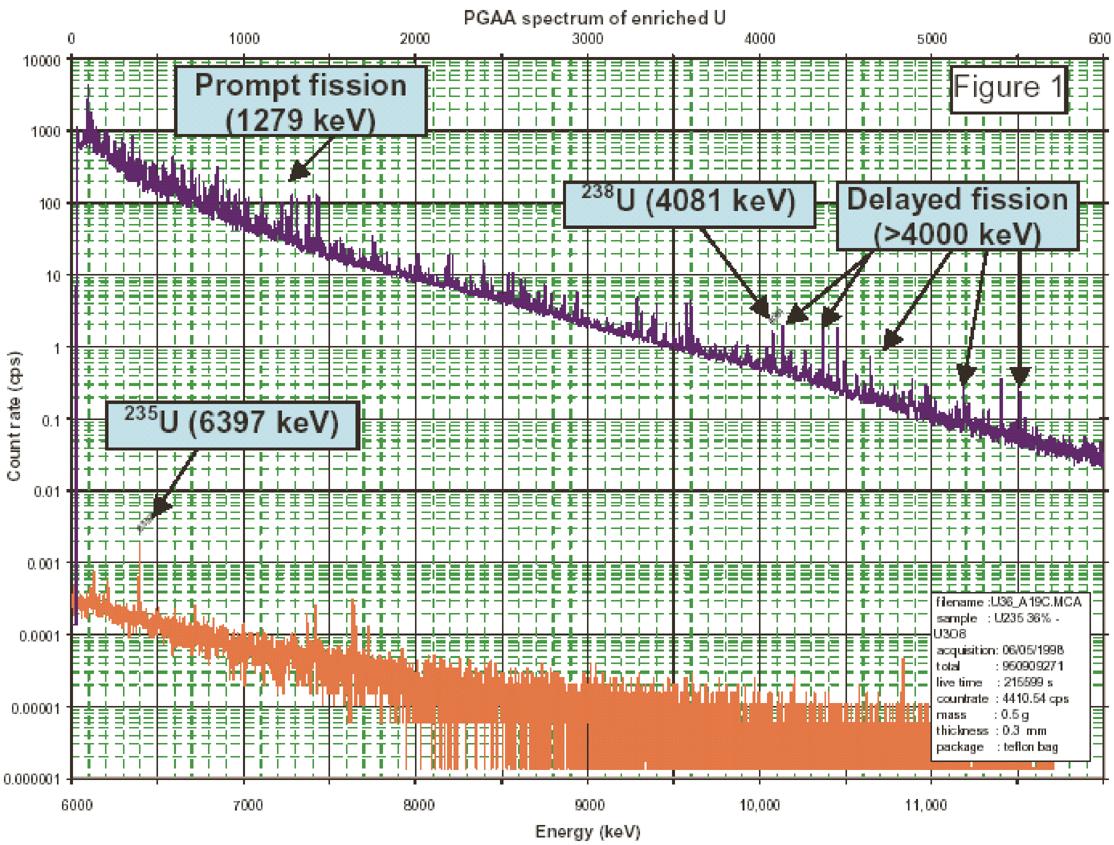

Figure 1. PGAA spectrum of 36% enriched uranium. Neutron capture gamma rays can be used to quantify both ^{235}U (6397 keV) and ^{238}U (4081 keV). Prompt and delayed fission gamma rays can also be used to quantify ^{235}U or other fissionable materials.

Actinide cross-section measurements require the preparation of chemically pure targets in compounds of fixed stoichiometry with anions such as chlorine for standardization. At Berkeley we have considerable experience handling actinides and preparing targets. Fig. 2 shows that both prompt neutron capture and fission gamma rays can be used to determine uranium depletion. We propose to include fission gamma ray yields in EGAF to support the quantitative determination of fissile materials.

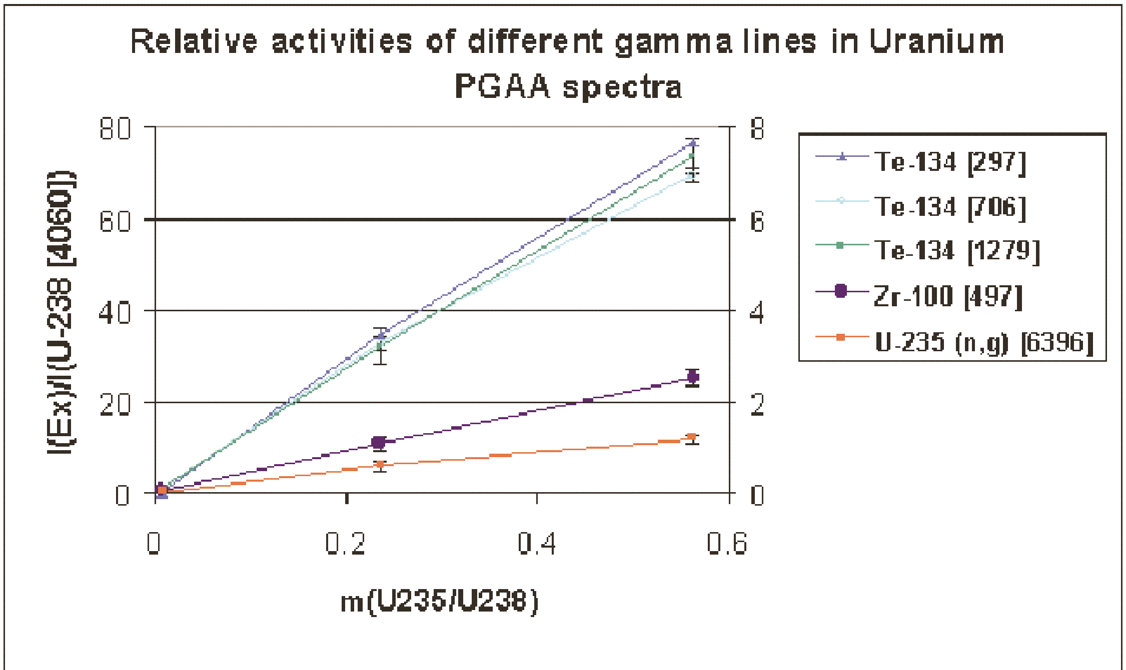

Figure 2. Analysis of $^{235}U/^{238}U$ ratios using PGAA. The intensities of various prompt fission and neutron capture gamma rays are observed to vary linearly with concentration for samples of natural uranium and uranium enriched to 19.1% and 36% in ^{235}U respectively.

At LBNL we have developed a new generation of neutron generators with self-loading targets, nearly infinite lifetime, and simple operation. At the LBNL D+D demonstration facility we have produced 10^{10} n/s, comparable to the best commercial D+T generators. The detection of Uranium with 2.5 MeV neutrons from the LBNL neutron generator is shown in figure 3. We propose to extend EGAF to include 2.5 MeV neutron capture gamma ray cross sections and fission yields to support the detection of fissile materials.

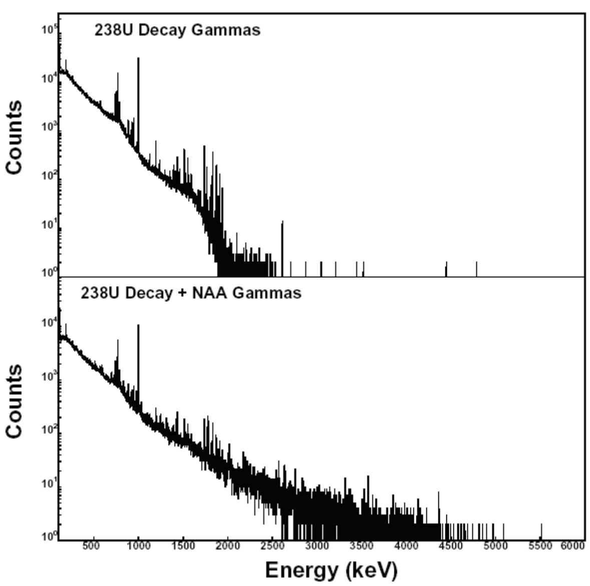

Figure 3. Detection of 0.8 kg of depleted uranium with 2.5 MeV neutrons. The top figure shows a uranium spectrum counted for 1 hour with a small 20% HPGe detector. Few gamma rays above 2.5 MeV are seen. The lower spectrum, accumulated for 6 minutes after a 10-minute bombardment, shows high-energy gamma rays from the decay of short-lived fission products. Many gamma rays between 2.5-5.5 MeV were observed. Analysis of the fine structure in the fission product spectrum may support the distinction of different fissile materials.

Proposed Technical Approach

U.S. citizen graduate students will be selected from a pool of recent applicants and assigned to relevant projects in actinide chemistry research. They will prepare isotopically pure targets of Uranium, Neptunium, Plutonium, and other actinide isotopes at the LBNL and the University of California Berkeley, Department of Chemistry. These targets will be analyzed with a well-standardized PGAA analysis system using the guided neutron beam from the Budapest Reactor. Both prompt and delayed neutron capture and fission gamma ray cross-sections will be will be measured using well-known internal standards. The data will be evaluated and compared to other data in the literature and to theory and added to the Evaluated Gamma Activation File (EGAF). Additional measurements of neutron induced fission and reaction gamma ray cross sections will be performed with 2.5 MeV neutrons at the LBNL Neutron Generator Facility and with14 MeV neutrons at the Berkeley Rotating Target Neutron Source and added to the EGAF. Experiments to develop neutron-based techniques for the detection of nuclear materials will be performed at the LBNL Neutron Generator Facility.

Cost and Schedule

We request three years of initial support for this project. This is based on the minimal time required to train PhD graduate students. In addition, we request 2 FTE of scientific staff support to supervise cross section measurement, data evaluation, and the operation and development of the LBNL neutron generator. Support for 4 FTE graduate students and travel and research supplies is also requested. There is an additional one-time request for detectors and associated electronics. The following budget is submitted.

FY 2004 Equipment Request:	HPGe detectors, electronics	$250K
FY 2004-2006 Annual Request:		
	2 FTE scientific support	$400K
	4 FTE graduate students	$200K
	Travel and supplies	$100K
	Total	$700K

Deliverables

Thermal, 2.5-, and 14-MeV neutron capture, fission, and reaction gamma ray cross-sections will be measured for a variety of actinide targets. The data will be evaluated and added to the Evaluated Gamma-ray Activation File that is maintained at the Lawrence Berkeley National Laboratory. This file will also be available to the U.S. nuclear attribution community from the National Nuclear Data Center at Brookhaven National Laboratory and from the International Atomic Energy Agency. Finally, the most important product of this effort will be a program of graduate student education at the University of California, Berkeley and the Lawrence Berkeley National Laboratory that will continue to supply a steady stream of new actinide researchers well into the future.